OIL DEFENSE

IN THE PACIFIC SOUTHWEST

RMERS' BULLETIN NO. 1848

S. DEPARTMENT OF AGRICULTURE

FOREWORD

The Pacific Southwest, as considered in this bulletin, embraces the two States—California and Nevada. Evidences of soil and water losses are briefly touched upon, as are the factors contributing to these losses. The bulk of the bulletin deals with measures of defense that are now being employed on farms and range land within project areas of the Soil Conservation Service and in areas where members of Civilian Conservation Corps camps have been assigned to erosion-control activities.

Three project areas are discussed in the section, Defense Measures in Action. The last section, Spreading Control Through Districts, deals with the new procedure whereby farmers may cooperate legally in a more appropriate use of the land.

Washington, D. C. Issued July 1940

Soil Defense in the Pacific Southwest

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Soil Conservation Service, in Collaboration with Subject-Matter Specialists

FARMERS' BULLETIN No. 1848

Contents

UNITED STATES GOVERNMENT PRINTING OFFICE

WASHINGTON : 1940

sale by the Superintendent of Documents, Washington, D. C. . . . . Price 15 cents

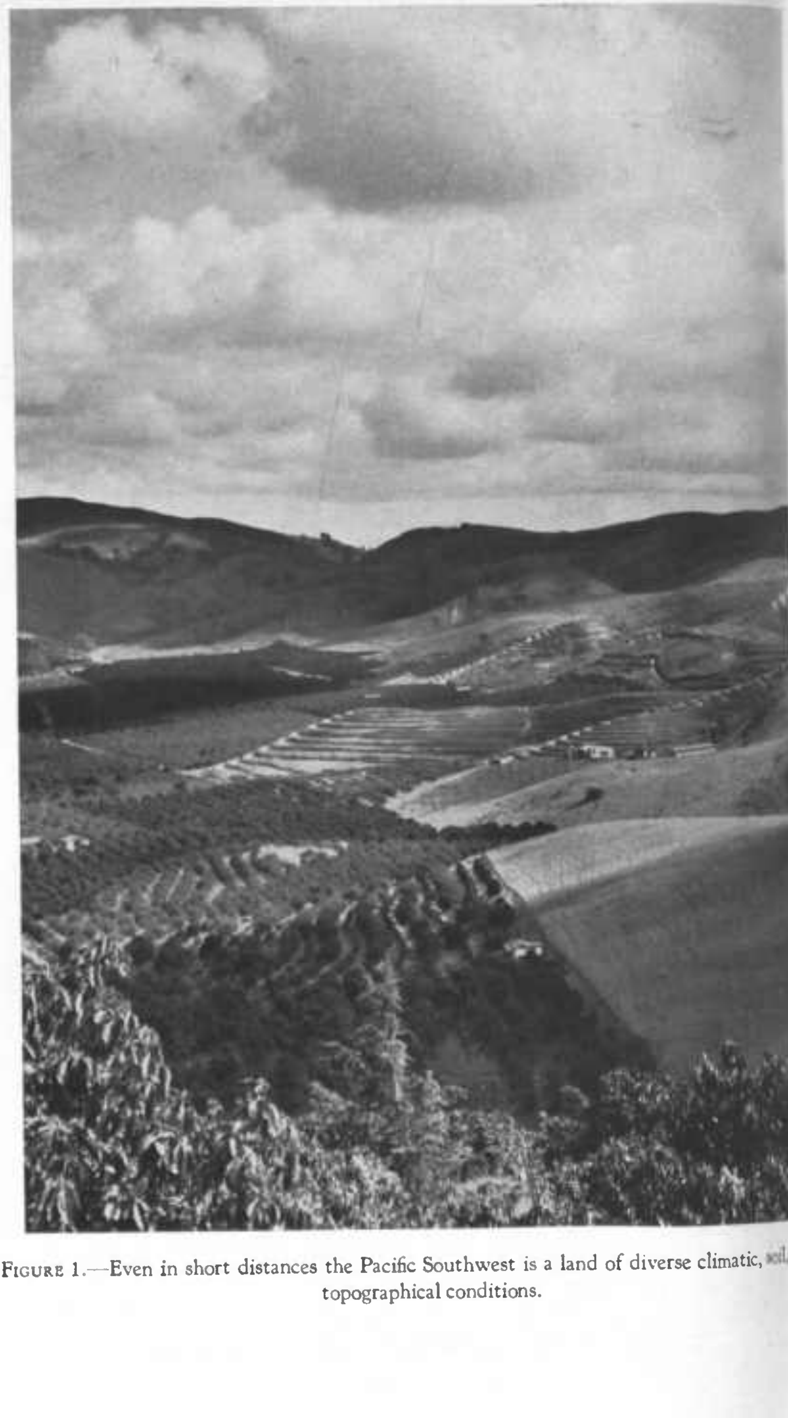

FIGURE 1.—Even in short distances the Pacific Southwest is a land of diverse climatic, soil, topographical conditions.

The Pacific Southwest

IF CALIFORNIA AND NEVADA, the States whose soil and water are here considered, were moved bodily to the eastern coast and superimposed at the same latitude, they would reach inland to Detroit, Knoxville, and Atlanta.

Those who are familiar with the Appalachian region with its fruit, dairy, and general farming areas and the contiguous sprawling belts of corn and cotton, are acquainted with a wide diversity of climatic, soil, and economic conditions. But the wide diversity of conditions found in these dozen or more eastern States is only partly suggestive of the variations to be found in the California-Nevada area; for the conditions in these Western States are very diverse within an area of a comparatively few miles (fig. 1). Snow-clad Mount Whitney, 14,500 feet above the level of the sea, is less than 100 miles from hot, dry Death Valley, which lies some 300 feet below sea level. People living in the sunny and almost tropical valleys need drive only a few miles in January and February to enjoy winter sports on the snow-clad slopes of the mountains.

All this suggests that climatic types range from alpine to desert. Localities with damaging frosts in midsummer contrast with those having a year-round growing season, and localities that have had 70 inches of rain in a single month can be contrasted with those recording no trace in more than a year. Below-zero temperatures are recorded in the high Sierras during the winter while summer temperatures in some of the valleys may exceed 100° F. C. W. Thornthwaite, in his study of climatic provinces and plant growth regions of the United States, found that 15 out of 23 regions were represented in the California-Nevada area.

Extreme as are the climatic variations, they are scarcely more diverse than the soil. The Department of Agriculture has already established over 270 series of soils in this region, and the number is increasing year by year as surveys are being completed. Many types can usually be found on a single farm.

As might be expected, with this complex pattern of soil and climatic conditions, one finds a wide range in the natural vegetal characteristics. In scattered areas, large and small, one finds sparse desert shrubs and cacti, sagebrush, chaparral, grassland, savanna, marshland, and deciduous and coniferous forests. Possibly nowhere else can one find species of trees, requiring heavy rainfall, that thrive in such close proximity to cacti which demand but little water.

These varied physical conditions provide the base for the wide diversity of agricultural activities. Immense expanses of open range land, both public and private, are used for the grazing of cattle and sheep. Extensive acreages are used for grain, forage, and other field crops (without irrigation). In certain thermally favored sections, subtropical fruits are produced successfully as far north as the latitude of Baltimore, Md., or Denver, Colo. But the extremely wide scope of agricultural products is possible only through the use of irrigation water. B. H. Crocheron, director of the agricultural extension service for California, found that this State alone, in recent years, has shipped in carload lots more than 180 different agricultural products.

Rough but conservative calculations based on the 1935 census report show that 38 million acres, or about 20 percent of the land in the region, is in farms. Of this, about 30 percent, or 11 million acres. is cropland, but exclusive of plowable pasture.

The land use pattern is at once distinctive and diverse. Less than 3 percent of one county (San Bernardino) is in farms; the remainder is sparsely settled mountain slopes and desert plains. Yet on this 3 percent, nearly $35,000,000

FIGURE 2.—Some "land" is worthless.

FIGURE 3.—Some land is used intensively.

worth of agricultural crops are produced. According to the 1935 census the production is sufficient to place this county in fifth position among all counties of the United States. In fact, 11 of the first 15 counties of the United States, grouped in the order of value of crop and livestock products, are within this region.

While the average value of all farm land in the region is roughly estimated at about $65 per acre, this figure does not reveal the extreme variations that are common. Some land is worthless (fig. 2). Other tracts may be worth $3 to $4 an acre for grazing purposes. Still others, though worth little even for grazing, may have a fairly high valuation if there is a possibility that water can later be supplied. On the fully developed citrus ranches land prices may be as high as $2,000 per acre (fig. 3).

Because of the diversity of climate, topography, soil, and economic conditions, one can find within these two States practically all of the characteristic types of agriculture in the United States. In some sections the agriculture is suggestive of cotton in the South, in others the wheat farms of the Plains, and still others the truck farms of New Jersey, and so on.

If the controls and cures for soil and water losses, discussed elsewhere in this bulletin, seem numerous, the reason can be found in the wide variation of conditions in the region.

Sea-Going Soil

GEOLOGICAL EROSION is an old process. It began with the first current of air and the first rain on this planet. For incredible ages wind and water have been wearing down our land surface. But this process went on leisurely, mysteriously, and with a natural balance that permitted soil-building agencies to replace soil as fast, or faster, than it was removed.

Geological erosion plays a part in building the soil and in making the earth habitable to man. Like fire, erosion can produce both comfort and destruction. Trouble starts when man through carelessness, ignorance, or necessity, disturbs the natural balance. When vegetation is removed from the land, by cultivation, fire, lumbering, or excessive grazing, the process is known as accelerated erosion. Under such conditions weathering can remove in a few years soils which took nature centuries to build. Those who take solace in the thought that erosion has always been with us, as indeed it has, disregard the difference between geological erosion under natural balance and cover, and the accelerated removal which begins with bared soil. It is accelerated erosion, not erosion in itself, that is considered here (fig. 4).

"Soil is rock material on its way toward the deep," wrote Shaler in Man and the Earth, 1905. But soils, he added, are "considerably restrained in going by the action of plants which form a mat upon them." He concluded:

> The preservation of the food-giving value of the soil as used by civilized man depends on the efficiency of the means by which he keeps the passage of the soil to the sea at a rate no greater than that at which it is restored by the decay of the materials on which it rests.

While Shaler and others, at the turn of the century, called attention to the accelerated removal of soil in the absence of a vegetative cover, it was not until 1917 that an attempt was made to measure erosion losses on agricultural lands. In that year M. F. Miller and F. L. Duley, of the Missouri Agricultural Experiment Station, installed the first device to determine soil and water losses under various crops and conditions. Their method, now somewhat refined and improved, is still standard. Strips of soil, of the same slope, lying side by side up and down the grade, are surrounded with treated wood or metal to prevent the entrance of run-off water or soil from the outside. Devices are provided, at the foot of each strip, to measure the soil and water loss. The strips are

lanted to crops or rotations of crops that prevail in the region. Experiments ich as these are now being carried forward and extended by 19 soil conserva-on experiment stations and by many State colleges and experiment stations. esults obtained through these widely scattered field stations provide the asis for our recent and more exact knowledge of soil removal and water losses ig. 5).

FIGURE 4.—Accelerated erosion.

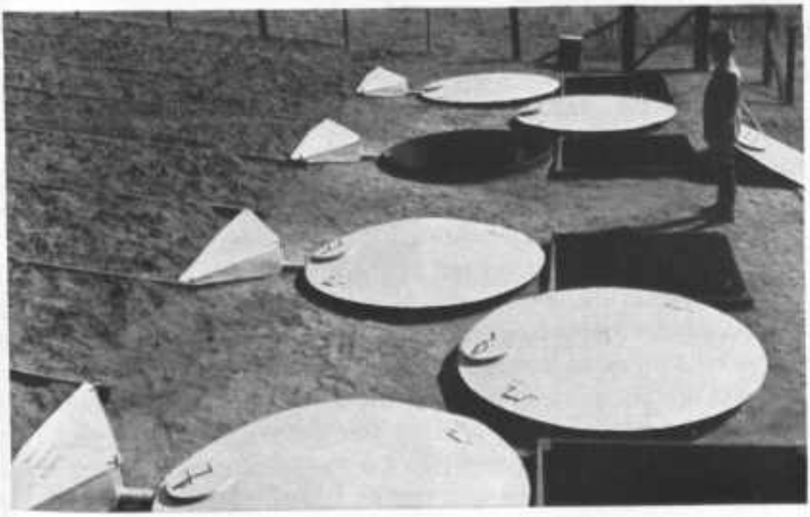

FIGURE 5.—Equipment such as this provides us with our recent and more exact knowledge of soil removal and water losses under varying conditions of cover.

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The immense amount of data on soil and water losses obtained from these experimental areas, as well as observations from general field activities have shown the effectiveness of close-growing vegetation in slowing down the run-off of water and soil. Soil and water losses are greatest where the land is bare of vegetation; next in magnitude are the losses from fields of cultivated or clean-tilled crops, such as cotton, corn, tobacco, and potatoes; and least in magnitude are the losses from ground covered with forest, grass, clover, alfalfa, and shrubs (fig. 6).

FIGURE 6.—Soil and water losses are severe where the land is sloping and vegetation is sparse.

Water and wind are the active forces of soil erosion. While wind erosion is active in a few areas within the Pacific Southwest, the amount of soil moved by the wind is very small in comparison with the aggregate amount of soil moved by water.

In general, water erosion may be divided into three types, sheet, rill, and gully erosion. Two or more of the types may occur simultaneously in the same field, and one type may develop into another.

Sheet erosion is the least apparent of the three types. It is the removal of soil in thin layers or sheets over entire fields by wind, or by water that is spread out rather evenly over the surface. Run-off water, under intense rainfall, tends to concentrate in streamlets. When these streamlets attain sufficient volume and velocity, small incisions, or rills, are cut in the land surface. These rills are easily smoothed out by ordinary tillage operations, and for this reason the loss is frequently overlooked. In the Pacific Southwest, sheet and rill erosion cause severe soil losses each year on those lands that are not provided with a cover of vegetation.

Usually gullies follow sheet and rill erosion, but they may have their begin-

ning in slight depressions of the land surface where run-off water normally concentrates. Then, too, they may develop in wagon or sled ruts which lead uphill over soft earth, or they may be formed by livestock trails and along furrows running up and down the slope.

Apart from the severe gashing and ruining of land, gullies collect run-off water and discharge it at maximum speed, damaging lower lands and increasing the hazard of floods and washouts. Furthermore, they discharge relatively poor and unproductive subsoil material upon lower slopes and alluvial plains.

The lighter, more fertile soil particles are whisked high in the atmosphere where they may be caught and carried hundreds, and even thousands of miles, as indeed they were on May 11, 1934. The heavier, coarser, and less fertile particles hug the surface until they pile up in drifts. The drifts may be small and easily leveled with ordinary farm tools; but they may increase in size, in extreme instances, until they take on dunelike proportions.

Measures of Defense

TOPSOIL COULD BE PRESERVED in the Pacific Southwest, as elsewhere, if all of the land susceptible to erosion was restored with nature's protective mantle of vegetation. But this procedure is impractical, for men must get their food from the land. Control measures outlined in the following pages are the best known safeguards to hold soil while deriving a living from it. Some of the safeguards have fully demonstrated their value over a period of years, while others are still on trial under a wide variety of conditions.

It is obvious to anyone familiar with the Pacific Southwest that watershed protection and stream control are vitally important. Without protection of the watersheds, and without means of controlling flood water, the agriculture and industry of the valleys are jeopardized. Even a brief discussion of ways and means to protect water supplies and to prevent damage by floods, is beyond the scope of this bulletin. As mentioned in the foreword, this bulletin deals, in the main, with measures that are being employed on farm and range land within project areas of the Soil Conservation Service.

Farmers can do nothing to alter or control the climate, nothing to change the natural topography of their land, nothing to change the basic materials from which their soils were derived. Most farmers can, however, crop and graze their land more skillfully. They can do something to make soils more permeable to rainfall and thus reduce the amount of soil-laden water carried to the sea.

Even with the best of soil management and even in a region where irrigated water must be used for maximum crop production, there are periods of heavy rainfall when it is impossible for the soil to absorb the water as rapidly as it falls on the land. Water that is not absorbed by the land must be disposed of, and the manner in which it is conducted off the land largely determines the extent of erosion control. All methods of conducting surplus water safely off the land are based on the simple principle of checking the rate of flow. Slowly moving water has no load of silt, and the cutting power is slight.

Management of Soils

It is apparent that if the permeability and water-holding capacity of a soil are increased, there is less surplus surface water to conduct off the land. In general,

the cultivated soils of the Pacific Southwest, as elsewhere, have become, through use, less permeable to rainfall. One reason, at least, for this decline in permeability can be traced to widespread and damaging overcultivation. Some of this overcultivation can be traced to the desire of neat farmers to have their groves and vineyards present a clean appearance. A part can be attributed to the reluctance to share moisture with any vegetation other than the money crop. Perhaps the most significant reason for overcultivation can be traced to the Campbell theory of dry-land agriculture, which, in the main, called for the maintenance of a dust mulch on the surface soil.

Continuous stirring of the surface soil hastens the depletion of organic matter. When the content of organic matter is reduced, the water-absorbing and water-retaining capacity of the soil is lowered, and the result is greater run-off when intensive rains fall on the land.

Following the break-down of the Campbell system (of insuring crops through the development of a dust mulch), there was a conscious swing from tools that pulverize the surface to those that dig deeply. This swing from shallow to deeper cultivation might have been completely beneficial if plans had been made to increase the organic-matter supply. In the absence of organic matter that had been destroyed by cultivation many soils of the region have developed a distinct plow sole which also has a tendency to reduce the infiltration capacity of the soil. The development of a plow sole thus increases the amount of water that must run over the land during heavy rains.

The wide variation of topography of soils in the Pacific Southwest has already been stressed. Few statements can be made relative to practices on cultivated land that have general application. There is general agreement, however, that the reduction and depletion of organic matter in the soil and the development of plow soles have made cultivated land in extensive areas more vulnerable to erosion.

Changes in Land Use

The most important initial step in the checking of erosion is to devote each parcel of land to the crop or rotation of crops to which it is best adapted. If the steeper slopes cannot be cultivated with safety through soil-conserving practices, or even pastured under an improvement program, they should be planted to trees (fig. 7).

Plants and cropping practices vary widely in the protection they provide against erosion. A pasture grass that forms a permanent dense sod may equal the virgin forest cover in protecting the soils. The worst offending crops are those that are widely spaced and of which intertillage leaves the surface soil bare of vegetation. The intervening soil is stirred and pulverized to kill weeds and, following the Campbell theory, to conserve moisture. In general these crops

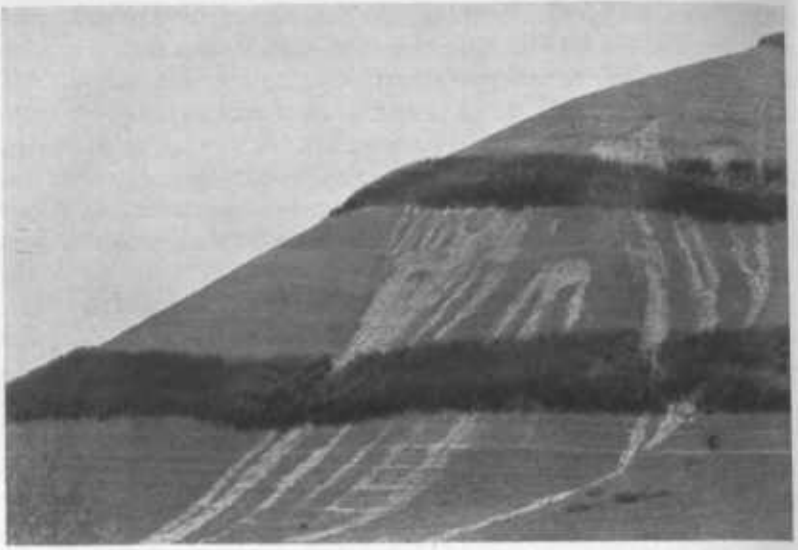

FIGURE 7.—Some slopes are so steep that cultivation is unwise. Even with strips of close-growing vegetation this field lost much soil and water.

have not been followed with winter cover crops, hence the soil has been an easy prey to winter rains. The so-called close-growing crops, such as wheat, oats, rye, and barley, are never intercultivated, and when harvested the stubble leaves some protection for the soil during the winter months. Summer crops of any kind which necessitate leaving the land bare in winter give no protection. In general, it is wise to seed the close-growing crops on the sloping land and confine the row crops to more level areas where erosion is not a problem or where it can more easily be controlled. Where a single crop is grown to the exclusion of all others, as in many areas that have a favorable climate, a change in crops might reduce the income if handled as a single crop. Such a change, however, may be imperative if the soil is to be saved. Later, conditions might warrant a more profitable crop that would lend itself to a soil-conserving program.

Numerous authorities feel that a Nation-wide policy of proper land use may be the eventual solution of many soil problems. Granting this point of view, many large-scale changes could only be brought about gradually. In the meantime, there are many changes that can and must be made on individual farms in order to preserve the economic independence of the farmer and the food and forage requirements of the Nation.

Cover Crops

Winter cover crops have been used by California orchardists for many years. Most of the orchardists, in the past, planted these cover crops for soil improve-

ment (fig. 8). Their value for green manure has long been recognized, and many growers, who now recognize that cover crops retard erosion on sloping lands, make every effort to establish the cover crop early so that it can stand guard against the heavy winter rains. Most growers prefer a fast-growing crop with a fibrous root system. Annual yellow sweetclover, bur-clover, field peas, or vetch mixed with oats, spring rye, or barley are crops that have proved satisfactory. Growers cannot determine, of course, when the first rains will come, but they try to have the crop seeded in the early fall so that it can take full advantage of the first available moisture from the winter rains. On irrigated lands the growers usually plant the cover crop just before or just after the last irrigation. On dry-farmed land, however, there is a chance that a good cover will not be secured some years because of a lack of rain at the right time.

In most cases it is necessary to use fertilizer to obtain a protective cover early enough to check erosion from the first heavy rains. Poor growth under moist conditions generally indicates a lack of readily available plant food. Under such a condition most growers have had good results by applying a commercial fertilizer that is high in available nitrogen. The cover crop is turned under after the heavy rains have passed but early enough to insure its decomposition in moist soil (fig. 9).

Continuous Cover in Irrigated Orchards

Viewed from the standpoint of erosion control alone, year-round or continuous cover crops in irrigated orchards have proved their value over annual winter covers. Moreover, continuous covers promote a more uniform distribution of water which in turn permits a normal spread of tree roots. But the problem of erosion control cannot be isolated from other problems of fruit production. For this reason, continuous covers that have been established on project areas of the Soil Conservation Service are being watched closely not only for their effect on erosion control but their relation to other problems connected with management.

Some of the questions that fruit growers and Service workers keep in mind in relation to continuous cover crops are: Will continuous covers help to maintain, increase, or decrease the average production and quality of fruit; will there be an increased use of valuable moisture; will the cost of pest control increase; will rodent losses increase; and are the covers practicable in different localities that have varying climatic and soil conditions?

These questions, and others that might be raised, suggest the need for widespread and exhaustive research. However, there are hopeful indications, based on the experience of a small group of growers who have abandoned clean cultivation in favor of a year-round vegetative cover. In 1938 the Soil Conservation Service observed 23 continuous cover-cropped irrigated orchards in various parts of California. Some of the orchards have been under cover but a few years while others have had this protection for as long as 22 years. Although the results re-

Figure 8.—Cover crops also retard erosion on sloping lands.

vealed in this study seem encouraging, and none of the 23 orchardists intends to return to the former practice of clean cultivation, the number of observations are too small to warrant a general conclusion.

A grower in San Diego County, Calif., has used continuous cover in his lemon grove since 1923. He planted his orchard, 8⅓ acres, in 1913 and used the usual system of clean cultivation and furrow irrigation until 1923. During these years he lost considerable soil through erosion by winter rainfall and irrigation. Since 1923 there has been little or no loss of soil or water under a continuous cover of bur-clover, annual bromes, and wild barley.

Clippings from the first mowing in the spring are placed in permanent irrigation basins, which are constructed at the drip of the tree and on the upper side. Subsequent mowings are left in place. Each tree normally receives approximately 1,000 gallons of water every 30 days during the irrigation season, or 14 to 19.2 acre-inches, depending on the length of the irrigation season which normally varies from 5 to 7 months. This is about the average amount of water used in lemon groves in this district.

Rodents are controlled by trapping, and the grower believes that under his method of operating this pest hazard is no greater under a system of continuous cover than under clean cultivation.

Of the 500 trees planted in 1913, all are producing good crops with the exception of about 6 which were severely injured during the freeze of 1937. The annual production between 1926 and 1938 averaged a little over 4,000 field boxes. The highest production, 1936, was 5,261 field boxes. The operator

states that growing costs have been materially reduced and that production and quality have improved.

On the River Road near Ukiah, Calif., 115 miles north of San Francisco, a 12-acre orchard of Bartlett pears may serve as another example of the use of continuous cover crops. The orchard was planted in 1888 on bottom land with soil 6 feet or more in depth. Four of the twelve acres were reset in 1919. Clean cultivation was practiced prior to 1923. Since that time the orchard has been under continuous cover.

Under clean cultivation the owner observed that water was not penetrating readily. Soil in a nearby alfalfa field, he noted, took water easily. As a result of this observation he decided to establish a permanent cover of clovers, Italian ryegrass, and other grasses in his orchard.

Crop yields secured from the packing-house record on 9.31 acres show that from 1926 to 1937 they ranged from a low of 15.7 tons per acre to 25 tons per acre. The average over this 11-year period was 17.8 tons of pears per acre.

The California Extension Service made an efficiency study covering a period of 10 years of the production of Bartlett pears in this rich fruit-growing district in 1936. Fourteen orchards were studied, of which the average yield was 6.9 tons of fruit per acre. Seven low-producing orchards gave an average yield of 4.1 tons as compared with 9.3 tons per acre by the seven high-producing orchards.

It appears, therefore, that the average yield of the Ukiah orchard under continuous cover was nearly three times the average of the 14 in the study, and over twice the average of the 7 high orchards that were reported. The report

Figure 9.—This Sonoma County, Calif., farmer is turning under his cover crop of barley and purple vetch.

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also shows that this orchard produced the highest acre yield and income of those investigated.

Though this idea of continuous cover in orchards is spreading rapidly throughout California, its use is most apparent in localized areas. The Placerville district in north-central California is a good example. In 1935, when the project area of the Soil Conservation Service was established, less than 25 percent of the growers were using continuous cover; by 1939 fully 75 percent had adopted the practice. Even the small group of growers who still cultivate have reduced the number of cultivations. Some of these cultivate but once in the fall and immediately seed an annual cover crop.

Not all of this retreat from cultivation to continuous cover, in 4 years' time, can be credited to the comparatively recent emphasis on saving soil. Before the establishment of the project, the local farm advisor had induced a few growers to try vegetative covers to prevent soil washing. Much of the spread of the practice in this district stems from these earlier demonstrations on scattered farms.

It is usually necessary to apply enough manure or other fertilizer for both the trees and the cover crop, particularly when the trees are young. Although a continuous cover of perennials may encourage rodents and other pests, the expense of combating these is compensated for by the saving made in cultivation costs and erosion prevention. Growers recognize the possible fire hazard but this does not deter them from the use of continuous cover.

FIGURE 10.—Slopes in this Eldorado County, Calif., pear orchard vary between 10 and 15 percent. A continuous cover of Ladino clover and Italian ryegrass was planted in the spring of 1937. The picture was taken on April 5, 1938.

FIGURE 11.—Cultivation up and down a slope invites the formation of gullies through which both water and soil may be lost.

Two types of continuous cover crops are being used in some localities in California, particularly in Placer and Eldorado Counties. One type consists of perennial grasses and clovers and the other is a combination of annual plants and natural weed growth. Redtop, Italian ryegrass, bluegrass, red clover, Dutch white clover, and Ladino clover are the principal plants used in a continuous-cover-crop program (fig. 10). The annuals consist of early maturing bromes, wild barley, fescues, and bur-clover.

Contour Cultivation

Map makers think of contours as lines which join points of equal elevation. The man on the land thinks of contours as level lines he can follow with implements across slopes. Here we have the cardinal principle of water and soil conservation, for farming operations become more efficient when they are conducted around or across slopes on the contour rather than up and down the hill. And contour cultivation should be used on all sloping land regardless of other control methods that may be employed. Cultivation up and down hill leaves sloping channels through which water readily flows. This practice invites the formation of small gullies through which both water and soil may move (fig. 11). Cultivation across the slope, on the other hand, leaves furrows which retard the water and allow it to soak into the soil. Even though the infiltration and water-holding capacity of soils vary in a wide degree, any tillage method which aids in getting water into the soil is of first importance.

FIGURE 12.—An illustration of "trashy fallow."

Trashy Fallow

It goes against a tradition of long standing to suggest the use of trashy fallow for soil protection. Trashy fallow gets its name from the trash or crop residue that remains on the surface (fig. 12). With scattered exceptions, most farmers have taken pride in completely turning under crop residues, such as straw, tomato vines, or cornstalks, as well as weeds. When soil conservation workers suggested the idea of trashy fallow, some farmers agreed to try it only on the back side of the grove where it would not be seen from the road. It is now recognized that trashy fallow, or trashy farming, as the practice is called on the Plains, is effective in helping to hold soil. The practice becomes even more effective if plowing is done on the contour so that a part of the crop residue sticks out at the edge of the furrow. Contour disking with a one-way disk mixes the crop residue with the surface soil and in effect builds thousands of tiny terraces and dams to impede run-off water. This practice can be followed in heavy stubble after combining and on dry soil where a double disk will not penetrate. The double disk pulverizes the soil, making it vulnerable to wind and water movement.

Some orchardists have found that trashy cultivation permits enough seed to mature from the previous crop to start a satisfactory volunteer cover for the following winter.

Basin Listing

The basin lister is one of several types of tools that represent a conscious swing from the early types that pulverized and leveled the surface soil to those now in use that dig deeply and throw up soil barriers to hold water (fig. 13). Basin listers are simply listers with basin-forming attachments. These attachments are designed to form a series of basins or cups in the soil to hold rainfall until it has time to soak into the ground. The basin listers cut furrows and automatically construct cross dams in them by the use of a special attachment. These special attachments can usually be fitted to a lister plow or to an irrigation furrowing implement. A recent improvement makes it possible to use the lister in a dual role for blocking furrows and for an irrigation channel.

The efficiency of basin listers is greatly increased if they are operated across the slope on the contour. The dams in the furrows take care of minor irregularities, keeping the water evenly distributed over the field by preventing accumulation at the low points along furrows. Since the dams are relatively weak and will not hold on much of a grade, any marked deviation from the contour should be avoided. Experience indicates that in most cases the furrows should not deviate more than about 2 percent.

On soils that take water readily the basin lister may be used on slopes up to 10 or even 15 percent, but on many soils 5 percent or less is the maximum slope on

FIGURE 13.—Basin listers form a series of cups or holes in the soil to hold rainfall until it has time to soak into the ground.

which it is effective. Since subsoil is usually less permeable than topsoil, basin listing is less effective on severely eroded land.

If the basins once start overflowing during a hard rain, they can be quickly destroyed. Deep cultivation and cover crops both tend to increase the rate of infiltration and thereby markedly increase the effectiveness of the basins (fig. 14). A cover crop may be seeded either before or after the basins are made.

FIGURE 14.—Basin listing with a heavy cover of volunteer clover, alfilaria, and wild oats. Prior to the time the picture was taken these basins were subjected to two heavy storms. There was no failure.

Basin listing is a good companion defense measure on terraced fields. The terraces will take care of extremely heavy rains and will prevent the formation of long gullies, while the basins will hold most of the water on the land between the terrace embankments.

Crop Rotation

Crop rotation has long been advocated as one of the major practices to insure the productivity of the land. But crop rotation, like other factors in soil management, seems not to have taken hold in any general way throughout the country. With the exception of the northern Atlantic Coast States, the eastern part of the Corn Belt in the Mississippi Valley, and a few isolated smaller areas, crop rotation has not been practiced. In general, in the South it has been cotton only; in the western part of the Corn Belt—corn; and on the Plains—wheat. It will not do perhaps to push this generalization further, but in the California-

Nevada region, crop rotation has not been given any more concern than in most of the other regions that are devoted to single crops.

Continuous cropping of land to tilled or row crops is not only conducive to decreased yields but it is also an important cause of erosion, a fact that is evident to anyone who will visit the single-crop areas of our country. Continuous cropping with intertilled crops depletes the organic content of the soil. In the absence of organic material the crumb structure of a soil tends to break down to single grains, which, like sand, are easily eroded. Both of these unfavorable conditions can be retarded by the practical means of rotation.

Close-growing cover and green-manure crops grown during the winter months, in rotation with tilled or row crops, will aid in the control of erosion. Apart from the protection these crops provide against rains, when turned under they add organic matter and improve the tilth of the soil. A good rotation usually includes legumes and legume-grass mixtures. Biennial or perennial legumes and grasses help to maintain the nitrogen supply, and the organic matter tends to preserve the aggregation of soil particles.

In sections of high rainfall, a winter cover uses the plant nutrients dissolved in the soil water and so prevents their loss through deep percolation. Crop rotation, in effect, renews the soil for each succeeding crop. Such renewal discourages the progressive increase of pests and diseases that attack more susceptible crops, such as peas, sweetpotatoes, and tomatoes.

Since rotations must be fitted to the specific crops, soil, and climatic conditions of each farm no specific recommendations can be given. Where rotations have been established, however, their value in conserving soil and maintaining yields has been abundantly proved.

Subsoiling

In some soils there is a layer of clay or a plow sole 8, 10, and sometimes 12 inches or more below the surface. Water does not pass through this layer readily, and run-off occurs with every heavy rain as soon as the shallow cultivated layer of soil is saturated. A subsoiler is commonly used to break up this impervious layer.

There are conditions under which subsoiling may be detrimental. Some lands have a clay layer too thick to be penetrated by a subsoiler. In other places soils are underlain by an impervious substratum. In either case soils are more often damaged than benefited by subsoiling. With heavy rainfall the soil mass becomes saturated and the underlying layer becomes slick. It is then that large areas of soil on slopes are likely to slide downhill in a mass. This process is usually called slippage.

Subsoiling, as is true with all other tillage practices, becomes more effective on sloping land if the work is done on the contour rather than up and down hill. Contour subsoiling may be all that is needed to hold soil on gentle slopes, but

usually less risk is involved if the practice is combined with other defense measures.

Strip Cropping

To strip-crop a field, the crops are planted in long and relatively narrow bands of approximately equal width across the slope on the contour. Clean-tilled crops (all erosion-permitting) are alternated with grass, small grain, and legumes (all erosion-resisting).

Soil-laden water flowing down from the clean-tilled strips encounters the bands of thick vegetation in the next strip below. Since the rate of flow is checked by the stems of plants, soil is deposited. In other words, the strips of close-growing vegetation serve as a filter, and both soil and water are retarded in the downward journey.

In the several grain-producing sections in California where biennial cropping is practiced, strip cropping can be employed with distinct advantages. By alternating strips of grain and fallow, erosion damage will be reduced. The fallow strips, particularly the straw and stubble that have been incorporated with the topsoil, will retard the run-off from early rains, and the crop strips will increase in effectiveness as the crop grows. The hazard of heavy loss by fire in grainfields will also be reduced by strip cropping.

Among the newer methods of conserving soil, perhaps strip cropping has been more widely used in recent years than any other. As with all control measures, the practice must be combined with other appropriate devices such as contour tillage, crop rotation, and terracing to obtain the maximum benefit.

Terracing

With the exception of the early earthworks to hold soil in North Carolina, South Carolina, Georgia, Virginia, and other Atlantic Coast States following the one-crop trails of tobacco and cotton, few terraces have been longer in use in the United States than those found on the clifflike slopes of California where avocados and citrus are sometimes grown. These permanent benchlike bands of soil, hugging the slopes, tier upon tier, resemble Old World terraces that have been in use for centuries (fig. 15).

But terraces on these steep California hills, in use for as much as 40 years, have been constructed, for the most part, with a different objective from that which prevailed in Europe. There the emphasis was placed on saving soil, while in California the major objective was to save water, and while effective in this regard, they have perhaps been even more effective in saving soil.

Strip-cover cropping and contour cultivation are the logical practices in an orchard that must be run on the contour to spread irrigation water. In practice the bench terrace is developed something like this:

FIGURE 15.—These permanent benchlike bands of soil resemble Old World terraces.

FIGURE 16.—In bench-terraced orchards, all cultivation is confined to a strip just above each tree row.

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The trees are planted in rows almost on the contour but sloping just enough to permit the flow of irrigation water. A strip of land below each tree row is left in grass or planted to a close-growing cover of vegetation. All cultivation is confined to a strip just above each tree row (fig. 16). Continued cultivation gradually moves the soil downhill onto the vegetated strip. This becomes steep as the cultivated strip is flattened. Thus, the slope is developed into a series of steps with a row of trees just over the edge of each step. Irrigation makes it possible to provide enough moisture for both the trees and the permanent strip of vegetation. Further protection against erosion is provided by a winter cover crop that is seeded on the cultivated strip just before or after the last irrigation.

Under this treatment there is practically no run-off and consequently no erosion even on steep slopes. Perhaps because bench terracing was originally used to facilitate irrigation on steep slopes the practice has been confined mainly to irrigated land. It is recommended, however, for dry-farmed land wherever there is sufficient moisture for both the trees and the permanent vegetal strip.

In some localities bench terraces have been put into the hillsides with a grader before the trees were planted. This practice is not generally recommended because it is very expensive as compared with the developmental method, which requires nothing more than the regular cultivation; also, by moving all the soil at one time, the steep riser where trees are planted is composed mainly of raw subsoil and entirely of loose material and is thus very susceptible to erosion and slippage during the first years while it is settling. Once such a slip starts it usually carries away each succeeding terrace to the bottom of the slope.

Even under conditions where lack of moisture would make the use of permanent strips of vegetation impracticable, it is recommended that orchards be planted on the contour so that cultivation can be done across the slope by following the tree rows. In general, the saving of moisture will more than compensate for that used by annual vegetation grown on the riser strip.

The Drainage Terrace

Though bench terraces have been in use for a number of years in California, only recently has there been an attempt to use the drainage type of terrace on lands devoted to beans or small grains. These terraces have a broader base than the puny and ineffective first earth ridges built by farmers in our overcropped Southeast (fig. 17). Hampered by a lack of engineering knowledge and of sufficient power to build really effective safeguards, the builders of many of the first earth structures failed to erect structures that would hold water and soil under the impact of heavy rains. Now, with an improvement in implements, engineering skill, and farming knowledge in general, it is possible to build structures which, though subject to still greater improvements, reflect the present-day conception of terrace design.

Terraces help to control erosion by intercepting the surface run-off at short

intervals and carrying it slowly off the field. Because there is always some erosion when water runs over bare soil, vegetation and proper tillage methods should be used further to protect the soil between the terraces.

The drainage type of terrace is a ridge of earth about 20 to 30 feet wide at the base and about 18 inches high at the center, running across the slope on a slight grade. These terraces are most effective on slopes up to 8 percent. The horizontal interval between them varies from 50 to 150 feet depending on the slope and the type of soil. The steeper the slope, the smaller the interval

FIGURE 17.—These terraces, swerving to the contour of the Pacific shore, help to check the downward march of sea-going soil.

should be. On soils not easily eroded the terraces may be farther apart than on very erodible soil. The grade of the terrace also depends on local conditions, and varies from level to 0.4 percent. The cross section should be sufficient to take care of the maximum run-off that can be expected from high-intensity storms.

As the success of a system of terraces depends partly on their being designed to meet specific conditions, the advice of an experienced man should be sought to determine the interval and grade. When these have been ascertained, the terraces can be staked out and constructed with little difficulty. A road grader is a suitable implement to use.

Terracing should be started at the top of the slope to avoid possible damage from rain before the job is completed. The terraces are usually constructed by moving earth to the ridge from both sides. The ridge should be built about 2 feet high to allow for settling and some flattening in cultivation.

When it is necessary to cross small gullies, the terrace should follow the general

slope of the land, and a fill should be made in the gully to maintain the proper grade. The difficulties involved in terracing a badly eroded field make it highly desirable to do the work before the land has become gullied and much of the valuable topsoil has been lost.

Properly constructed terraces may be crossed with farm machinery, but all cultural operations should be parallel with the terraces. If deep furrows are cut through them, seepage of water may cause breaks. In plowing, a backfurrow should be plowed on the center of the ridge and a dead furrow left in the water channel. In this way, the terraces can usually be maintained without special operations, although it is desirable to keep the channels open with a grader or scraper.

Grade Ditches

When slopes between 15 and 25 percent are in cultivation, conservationists on project areas of the Service generally recommend the use of the grade ditch. This ditch is similar to the terrace except that a definite water channel is made and the earth removed is piled up to form a narrow ridge. This ridge is then planted with a buffer strip of a close-growing cover to prevent washing.

While these grade ditches help to hold soil and check the development of gullies, they cannot be expected to do an adequate job if the slope is subjected to the punishment of clean cultivation. Grade ditches, as in the case of practically all other control measures, should be supplemented with other safeguards such as cover crops and contour tillage. In general, such slopes should be used for an erosion-resisting crop, or, even better, they should be taken from cultivation while there is sufficient topsoil to permit trees or pasture grasses to be established readily.

Annual Ditches

Square-planted orchards, even if they are provided with a cover crop, may be subject to severe erosion in winter months if there are heavy rains. Small grade ditches on the contour that wind in and out among the tree rows have proved effective in removing excess water without damage (fig. 18). These ditches, little more than plow furrows, are constructed before the first rains are expected each fall and just before the cover crop is seeded. They are given a slight grade, just enough to carry the water.

When grade lines are established for these annual ditches, many growers paint a number on the nearest tree and on the side of the tree nearest the grade. This paint mark tells the number of feet from the grade line to the tree. The grower turns the cover crop under in the spring and the ditches are leveled. When he wishes to construct new ditches the following fall, he can locate the grade by consulting the figures on the trees.

FIGURE 18.—Small grade ditches carry excess water without damage.

Terrace Outlets and Outlet Structures

Apart from the faulty design and the lack of supplementary protection by vegetation which have characterized terracing failure in North America, perhaps the chief oversight has been in not providing safe methods of discharging water from terraced fields. The hasty and cheap method of terracing sought simply to dump the water and forget it. Water concentrated by terraces or other earthworks is the direct cause of gullying in far too many instances, and water discharged in this way has torn up highways or land in adjacent fields.

Unless water from all graded terraces or ditches is taken care of, it will form a gully down the slope and cut back along each terrace or ditch. To avoid this, some form of outlet ditch must be provided to carry the water safely to the bottom of the slope.

In sections where the amount and distribution of rainfall are sufficient to allow a sod to become established, it is possible to protect outlet ditches on moderate slopes by this means (fig. 19). Sodded ditches must be broad and shallow in order that the velocity, and hence the cutting power, of the running water be kept as low as possible.

Sod-forming grasses that are sufficiently drought tolerant to survive the long dry summer have been found to be the most suitable vegetation for ditch protection. Quick-growing grasses, such as ryegrass, are desirable to produce a cover the first year.

Ditches on very gentle slopes should not be planted but rather should be kept

clear of vegetation in order that sufficient velocity of flow can be maintained to prevent their filling with silt.

Unless irrigation water is available, the low rainfall in parts of California makes sodded ditches impractical, and on highly developed citrus and avocado land the necessarily large size of this type of ditch is undesirable. In such cases it may be necessary to protect the ditch with an artificial lining (fig. 20).

The most satisfactory mechanically controlled ditch is one lined with concrete, masonry, or some bituminous mixture, such as is used on roads. The lining prevents all cutting and permits the ditch to be of minimum size because the high velocity of the running water gives these ditches large capacity.

Terrace outlets that convey the run-off from the terrace into the main outlet ditch are necessary to prevent the water from cutting off the lower end of the terrace and forming a gully parallel to the outlet ditch. The terrace outlet may be a small cut-off wall at the end of the terrace or a notch left in the side of the lined ditch. The outlet should be broad and level in order that the water may enter the ditch in a thin sheet that will disturb as little as possible the flow of water in the ditch.

The use of underground pipe lines for outlet channels is of particular value in orchards where an open ditch would seriously interfere with cultivation. The terrace outlet for use with underground pipe is a small upright pipe, flared out at the top. These outlets are usually placed in the tree rows where they permit cultivation in one direction without interference.

Frequently a natural drainageway through a small gully may be used for the outlet ditch. It is often necessary to put in a series of small dams to prevent

FIGURE 19.—A vegetation-lined ditch with pipe and wire check dams after a storm.

FIGURE 20.—On highly developed citrus and avocado land an artificially lined ditch is frequently practical.

further cutting. The usual practice is to arrange the dams and terraces so that each terrace outlet is immediately above a dam.

Terrace outlets into a gully take the form of chutes to carry the water to the bottom of the gully without cutting into the banks. For this purpose short lengths of pipe, masonry chutes, or a half-round of corrugated pipe may be used. These terrace outlets can very often be made a part of the wing walls of the dams at little additional expense.

Gully Control

On December 10, 1799, George Washington wrote his farm overseer, a Mr. Anderson:

> * * * gullied parts ought to be levelled and smoothed and * * * covered with litter, straw, weeds, corn stalks, or any other kind of vegetable rubbish, to bind together, and prevent the earth from gullying.

About the same time that Washington was writing lengthy memoranda about the management of his farm, Thomas Jefferson, 100 miles to the southwest, was trying out horizontal plowing and other methods to hold soil. Another Virginian, Patrick Henry, in one of his famous speeches, soon after the Revolution, said: "He is the greatest patriot, who stops the most gullies."

But neither Washington, Jefferson, nor Henry seem to have appreciated any more than most people, then and now, the far more damaging and more subtle

action of sheet erosion, for most gullies are a result of uncontrolled sheet erosion. It follows then that an adequate program of defense on the field will do much to prevent gully formation. This, however, is knowledge inspired by hindsight observation, and if gullies are already destroying a field the problem is to check their growth.

Gullies often grow very rapidly. They are lengthened by headward erosion caused by water cascading into the upper end of the gully and eating back into the higher land, or by deepening of small rills to the extent that they can be classed as part of the gully. This deepening of gullies is caused by rapidly flowing water scouring out the bottom of the channel and continues until the grade of the gully bottom is so reduced that the water flows too slowly to cut farther. Gullies are widened by the meandering of the stream with consequent undercutting and caving of the banks. Controls must be provided to prevent growth in each of the three directions.

Small Gullies

Terracing or other control practices on the land above will often divert, or greatly reduce, the flow of water entering the heads of small gullies and will make other head-control measures unnecessary. In cases where a gully must be used as a drainage channel, a chute or overfall should be placed at its head so that the water can reach the bottom of the gully without cutting the sides.

Head control for a group of closely spaced gullies can often be done most economically by installing a diversion ditch around the upper ends of all of them and leading all the water to a single chute or overfall. When the rapid headward cutting has been stopped by reducing the flow of water in this way, vegetation can become established and complete the control.

Vegetation provides the least expensive method of controlling the meandering and downward cutting of a gully. In many cases the banks can be sloped and the channel made relatively broad. One of the sod-forming grasses will then hold the soil against the running water. By straining the silt from the water, these grasses cause the gully to fill up gradually with silt. A gully that has been thus reduced to a gently sloped, vegetated depression need not seriously interfere with cultivation, as the implements can be raised in crossing it.

It is often necessary to install a series of simple dams in a gully to prevent cutting until the sod has become established. Where the flow of water is relatively small, living dams of Napier grass and willow have been used with satisfactory results. In using vegetative dams care must be taken to keep the center low and open to avoid diverting the water against the banks and cutting out the dam.

With large flows of water and steeper grades, a more substantial dam is usually required. These may be of logs, brush (fig. 21), or pipe and wire, but masonry or concrete are preferred. Though expensive in first cost, they are

usually more conomical over a period of years than the less durable materials.

Dams are so spaced that the top of one is slightly below the bottom of the next one upstream. Silt is deposited on a gentle grade between the top of one and the bottom of the next so that water flows slowly between them. Vegetation can then be established in the bottom of the gully to build it up and on the banks to prevent widening of the gully by meandering.

On valuable land a small gully that could be controlled with vegetation is sometimes better treated by installing a series of dams. The banks can then be gently sloped and the land between the dams used for crop production.

Large Gullies

No better argument for controlling erosion in its early stages can be found than the large gullies that are taking great tracts of land from cultivation.

Every large gully presents its own problem. The value of the land, the type of soil, and protection to roadways, bridges, and private property along the entire course of the gully are factors to be considered. Where economically feasible, large dams are effective in controlling further cutting. Evidence of local opinion as to the value of such structures is indicated by the fact that corporations as well as groups of farmers have built such structures costing as much as $30,000 in Ventura County, Calif.

Figure 21.—This gully, caused by run-off from the road above, is now under control by the use of brush for check dams.

With proper location of dams even large gullies can sometimes be silted up in a few years, thus reestablishing fields and reclaiming land to justify amply the expense.

Chutes and diversion ditches are used to control head erosion. A

few dams are installed to prevent further cutting in the bottom, and, where possible, vegetation is established at the foot of the banks to prevent undercutting. Napier grass, willow, and strong sod-forming grasses have been successfully used for this purpose.

Where soil conditions are favorable, sloping the walls of these gullies and then establishing vegetation is one way of completely controlling the further encroachment on good land. This sloping, especially where the walls are vertical, necessarily involves the sacrifice of acreage which, on valuable land, may seem prohibitive. It must be borne in mind, however, that the gully will, in the course of years, no doubt greatly increase in width by bank cutting and thereby magnify the problem.

Reclaiming Land by Narrowing Gullies

Some gullies, while not deep, have cut wide channels through valuable land. In order to prevent further losses and possibly even to reclaim some of this land, revetments may be constructed along each side and earth filled in behind them. These wall-like revetments should be placed just far enough apart to leave sufficient channel for all water that may be expected to flow through the gully.

The revetments are usually constructed of used pipe or posts and woven wire in the form of a fence. Brush is packed behind the revetment before the earth is piled against it.

Several kinds of trees, shrubs, and grasses are also suitable for revetments. Willow posts have been used with good results. They sprout to form a living barricade while their roots extend under the channel where they help to stabilize the bottom. Cottonwood and sycamore are other trees that may be used. Napier and pampas grass have also proved effective.

In using vegetation for revetments and other control measures, care must be taken in selecting the kind of plants suited to the soil and moisture conditions of the particular location as well as to the climate. The plants must be cared for during their period of establishment and must be trimmed and guided during growth to prevent the channel from becoming choked with vegetation.

Erosion Control on Range Land

In the Pacific Southwest, in common with other semiarid regions, management is the key to erosion control on range lands. The improved management practices have been developed through the experience of stockmen and by the research activities of State and Federal agencies.

Experienced rangemen usually mention a four-point program of management for the restoration of a range. These four points relate to (1) number of animals, (2) kind and class of livestock, (3) season of use, and (4) distribution of stock over the range.

Number of Animals

Most rangemen agree that proper stocking as to numbers is the most important single factor in the protection of forage (fig. 22). It is useless, they say, to take steps to protect and improve a range if hungry animals are allowed to nip off vegetation as it emerges into view. The whole history of the range, which reaches back more than a half century, shows that the sparse plant cover is the result of a long period of stocking beyond the grazing capacity.

FIGURE 22.—Proper stocking is the most important single factor in the protection of grass.

But this point of view is challenged by those who claim that the present depleted plant cover is the result of droughts. Droughts have, of course, had their effect, but evidence indicates that droughts, in the absence of overstocking, would not have caused a change in plant species, excessive losses of topsoil through erosion, and arroyo cutting at a rate for which there is no known precedent. It is not uncommon to see good grass and little erosion on one side of a fence and meager cover and severe soil loss on the other.

Most of those who take the point of view that droughts are the chief cause of range depletion believe that the climate has changed or is changing. If weather reports, which date back 60 years, and tree-ring studies, which reach back for several centuries, do not mislead, then there is no reason to believe that the climate has changed. These records show drought periods, normal periods, and periods of above-average rainfall. Before the white man drove his teeming herds onto the range, the grass recuperated sufficiently after droughts to check soil erosion and not let it get out of control (fig. 23).

By and large, overstocking has been most prevalent at times when the grass was least able to stand the abuse. It has worked something like this: Following several years of drought, livestock numbers were curtailed. When rains came, the grasses recovered and thickened, and livestock numbers were increased to take advantage of the increased forage and higher meat prices. But when the drought years returned, the range was overstocked and meat prices reflected the increase in numbers. At this point, stockmen were inclined to hold their animals in the hope of better prices or rain.

Prior to the passage of the Taylor Grazing Act, the stockman as an individual could do little to protect the unreserved and unappropriated public domain. It was evident that the old unwritten agreement "first come, first served" applied to the use of the range. The stockman reasoned, and with wisdom, that if his stock did not get the grass, it would be taken by animals belonging to others. Even under private ownership, ranges may deteriorate because of high overhead charges which force stockmen to stock their range too heavily. But on public lands, without some measure of control by lease or permit, the individual stockman is even less able to adjust livestock numbers to grazing capacity.

No rule-of-thumb methods are appropriate in figuring grazing capacity. This can be done only through a careful survey of the entire range to determine the amount of available forage on each unit. Range surveyors take into consideration the density of plant cover, the proportion of perennial grasses, browse plants, and weeds (fig. 24). They also take into account the plant usability of

Figure 23.—Before the white man drove his animals onto the range, the grass recuperated sufficiently after droughts to check soil erosion and not let it get out of control.

Figure 24.—Mounted range surveyor considering the density of plant cover, the proportion of perennial grasses, browse plants, and weeds.

various species. With this information at hand, it is possible to make an estimate of the number of animals the range will properly support. However, the estimate must be used as a guide only. The condition of the range will determine whether the number of livestock should be increased or decreased.

Overstocking is prevalent on many of the small irrigated pastures. Some range men have overlooked the fact that the forage in these comparatively small pastures will decline in time if controlled grazing is not practiced. Even with plenty of water available the more desirable pasture plants will be replaced by less desirable species if overgrazing is permitted. In this respect, the pasture problem in irrigated valleys is similar to that in the humid areas of the country (fig. 25). The solution lies in both the improvement of pasture forage and a reduction of the livestock. The alfalfa acreage in many irrigated valleys might well be increased for pasture purposes.

Seasonal Use

The Pacific Southwest, in common with other semiarid regions, is noted for the wide variation in the amount of forage produced yearly. This wide variation is caused principally by the erratic character of the rainfall. The response may be general or localized; on one ranch the high and low of forage production may be as extreme as over large areas.

The objective, of course, is to restore the vigor and density of plant cover, but this objective cannot be attained if vegetation is not given an opportunity

FIGURE 25.—Overstocking depletes the cover in irrigated valleys.

to reseed. Where forage production varies so widely, a system must be provided that allows for alternating periods of use and protection. On range land suited to year-long use, the deferred-rotation plan of grazing provides protection during the seed-producing period on a portion of the range unit each year.

Fencing costs and the necessity to handle stock frequently are among the objections most often voiced against this system. These objections are not valid, however, when weighed against the loss of forage and plant cover. Without the protection of deferred rotation grazing, plants are closely clipped in patches and trampling is induced.

Winter ranges are frequently damaged by permitting livestock to graze too late in the spring. Likewise, spring ranges are often abused by permitting livestock to graze too early. The proper time to remove animals from a winter range or to turn on a summer range can be determined only by the condition of the forage. Some ranges are so depleted of forage through drought and overuse that a complete rest is necessary for recovery.

Spreading the Livestock

The familiar comment "salt is a cheap cowboy" has its origin in the aid salt can give, if properly distributed, in spreading animals over a range. If salt is placed in little-used areas between watering places, it helps to spread livestock over the range. Cattle tend to graze back and forth between salt and water. If salt is placed near water, it tends to cause animals to mill around in a concentrated area until the cover is damaged or completely destroyed.

There are other equally important methods that help to secure a more even distribution of livestock (fig. 26). Fencing, the development of additional water facilities in areas of good forage, and herding are among the methods most commonly used.

Good Management Pays

Apart from the fact that conservative stocking and other improved methods protect the range and reduce erosion, there is evidence which indicates that these practices also give greater gains in weight of cows and calves, heavier wool clips, larger crops of calves and lambs, and smaller death losses.

While several demonstrations are now under way in the Pacific Southwest to determine the increased returns which may be expected under improved range management, most of these demonstrations have not been established long enough to show conclusive results. An idea of the possibilities, however, may be gained by reference to work now under way in New Mexico on the Navajo Indian Reservation. Twelve demonstration areas, from 4,000 to 38,000 acres each, were selected by the Soil Conservation Service in cooperation with the Indian Service.

The Ganado demonstration area of 8,000 acres was stocked to grazing capacity in the fall of 1935. The results of this demonstration are reported in Miscellaneous Publication 338, Soil Defense of Range and Farm Lands in the Southwest.

The lamb crop inside the area in the 1935–36 grazing season was 93 percent. Lambs averaged 7½ pounds and brought 7 cents a pound, a premium price. At marketing time, the oldest lambs

FIGURE 26.—If adequate in size and spaced properly, water-storage facilities help to distribute animals over a range.

were only a few weeks over 5 months of age. All were born within a 35-day period. Traders in the vicinity paid a premium because they had contracted to supply buyers with lambs which averaged 55 pounds. The heavier demonstration lambs were in demand to bring up the average weights.

* * *

Outside the area, the lamb crop was 61 percent, a third smaller. The average weight of the lamb was 45 pounds, a third less. They brought only 5 and 6 cents a pound. Since the bucks had run with the ewes throughout the year the lambs were of various ages, from 6 to 8 months old, and lacked uniformity.

Inside the area the average wool clip from the ewes was 8.17 pounds [per sheep unit]; outside the area, 5 pounds, a difference of 3.17 pounds. At 25 cents a pound for wool and 6 cents a pound for lambs, the income per sheep unit inside the area was $5.78; outside the area, $2.90, a difference of $2.88 in favor of the demonstration sheep. The prices received for fleeces and lambs from inside the area were higher than the prices received for fleeces and lambs produced outside the area.

In the grazing season of 1936–37 the record was even better. The lamb crop was 98 percent, 5 percent higher than in the year before, and lambs averaged 73 pounds weaned for market. Traders said lambs outside the area were averaging 55 pounds that season, or 18 pounds less than the demonstration lambs.

Irrigation Practices

When water costs are high, men usually use care in distributing water for irrigation purposes. This is particularly true in southern California where the high costs of obtaining water have imposed an efficiency of use which is without parallel in the world. Yet even here examples may be found where unwise irrigation has led to soil and water loss. These examples, in the main, are confined to those irrigation systems which were laid out and constructed prior to 1920 or before effective engineering knowledge was applied.

The efficient use of water in some other irrigated sections in California is in sharp contrast with that of southern California. In these other sections, where water is cheap and where land values are low, water is often used carelessly with resultant losses in both soil and water.

Soil and water losses seldom occur in the broad and fertile valley floors, because nature left the land on such gentle slopes that it is generally ideal for irrigation. But these valley floors are surrounded with slightly steeper lands which, in turn, are usually bordered by sloping foothills. Although it is not generally appreciated, rich soil may be formed on hillsides, and a large portion of the fertile hillside land is irrigated. It is on these lands, with the steeper gradients, and the foothill areas with tilled slopes, frequently of 50 percent or more, where improvements in irrigation practices are most needed.

Erosion losses on irrigated land are usually caused by the furrows being too steep or too long.

When furrows are too steep, practically any amount of water will flow fast enough to cause erosion. A direct result of this practice can be found in many orchards where the topsoil on the upper slopes has been removed, while the lower portions have been seriously covered.

When furrows are too long, even though the grade is correct, water in large heads must be run through long after the soil of the upper slope is saturated in order to give the water time to reach the far end. This large flow of water carries soil with it.

A broad flat furrow is preferred to the V-shaped type in common use. A broad furrow provides a good seedbed and practically eliminates erosion which consistently occurs in the V-shaped irrigation furrows. A machine recently developed by the Division of Irrigation in cooperation with the University of California provides this desirable type of furrow.

Damage from unwise irrigation practices is apparent in the foothill section of the Sierra Nevadas, particularly in El Dorado, Placer, and adjoining counties. In one project area, Placerville, 60 percent of the soil losses from erosion are attributed to irrigation practices. This area is an important deciduous fruit belt that supplies the market with one-third of all this type of fruit produced in the State. The major portion of these orchards is irrigated. These farm lands and orchards were developed following the gold-rush days, and the present water companies operate under the same water rights established by the placer or hydraulic miners in the early days. When the orchards were laid out, apparently no thought was given to proper irrigation grades. The trees are, for the most part, square-planted, regardless of the fact that the topography is irregular and rolling. In general, the irrigation is down the steepest part of the slope and is done on grades ranging from 10 to 30 percent.

Apart from the erosion losses in orchards caused by unwise irrigation practices in this district, perhaps the most severe losses are in the more open areas that are devoted to field crops. Here the farmer usually attempts to economize on the cost of installing pipe lines or other distributing methods. Consequently, he uses excessively long runs or furrows.

Where damage is caused by improper grades, usually resulting from running the furrows directly down the slope, the irrigation system should be changed. The pipe lines should be run down the slope with heads so distributed that irrigation can be accomplished without cutting.

In the case of excessively long furrows on suitable grades, the damage can be prevented by installing additional pipe lines parallel to those already in use. Present evidence indicates that in many instances the savings in water and its more even distribution would offset the cost of installing additional lines.

In the Sierra Nevada foothills and in other fruit-growing sections, permanent cover crops have been used in a number of orchards. The heavy vegetation on the ground spreads the irrigation water uniformly and prevents erosion even on steep slopes. A pipe line or ditch at the top of the slope supplies the water, although on long slopes additional pipe lines or pick-up ditches may be necessary to assure a uniform distribution of water.

Basin irrigation is used in many places, particularly in avocado orchards,

where little, if any, cultivation is done and the basins are permanent. In some cases a pipe or faucet is provided for each tree. In other instances, water is run down across the slope from one basin to the next in a zigzag course.

Sprinkling systems are used in many citrus orchards. With care, water can be applied at a rate which permits it to soak in as fast as it falls; thus there need be no irrigation run-off or erosion.

A large number of examples of both good and bad irrigation practices could be cited. Near Uplands, in San Bernardino County, Calif., there is a lemon orchard which was first planted in 1895 on what is generally termed "a contour system"; that is, the trees follow approximately true irrigation grade lines. That orchard is still owned and successfully cultivated by the same man who laid it out. While the topsoil may have shifted to some extent, it has remained in the orchard where it belongs, the trees have a good appearance, and crop records indicate satisfactory production.

Immediately surrounding this grove are other orchards that were laid out for irrigation down the steep part of the slope, but in many cases, because of excessive erosion, the original orchards have been replaced by new trees. In spite of such evidence, however, they are still being irrigated on grades that cause each succeeding irrigation to move substantial portions of the topsoil from the upper end of the farm to the bottom, if not entirely off the land.

At Chino, there is an orange grove of 208 acres consisting of several individually irrigated blocks planted on the alluvial fan of a side canyon that has an average grade of 4½ percent. Pipe lines were installed to run the irrigation water down this 4½-percent slope; but even before reaching maturity the orchards began to decline in production, and the original owners were glad to sell to the present owner at a sacrifice.

With the help of technicians from the experiment station and the agricultural extension service, the new owner concluded that the decline in production of the orange grove was caused by the fact that the upper end of each block of the orchard had been seriously eroded. This fact was evidenced by irrigation stands and trees standing on mounds in the upper portions of the orchards, while the trees at the lower ends were literally buried under deposits of soil as much as 18 inches in depth.

Three dump trucks and a tractor-loading device were purchased by the new owner, and the "wandering" soil was scooped up and returned to the upper portions of the orchards. New irrigation pipe lines were installed which provided for irrigation along the cross rows on a grade of approximately 1½ percent. Within a few years nearly all the trees recovered and now have a uniform appearance over the entire 208 acres. The change in irrigation practices has practically eliminated erosion.

The beneficial effects of returning the soil has been substantiated further by a comparison of yields. In the spring of 1935 a picking from each box row ran between 1,000 and 1,100 field boxes. The box rows followed the new irrigation

rows and thus served as sample strips across the steep part of the slope, and the slight variation in the total number of boxes seemed to have no relation to the location of the rows in the orchard. In other words, the formerly eroded ends of the orchards now produce their full share of the crop.

A citrus and walnut orchard in Orange County may be used as another example. It was originally laid out and irrigated in such a manner that the irrigation grade was a contributing factor in the resultant erosion. The length of the irrigation runs was about 800 feet. Ten years ago the owner installed three new pipe lines, cutting the length of the irrigation runs to about 200 feet each. Since that time he has been able to maintain a uniform distribution of water; and although he continues to irrigate on the same slope or grade as before, the size of each stream and consequently the velocity of flow has been so reduced that, with the aid of cover crops, very little erosion results either from irrigation or the winter rains.

Defense Measures in Action

THIS BULLETIN HAS REPEATEDLY stressed the point of view that single control measures are usually ineffective in holding water and soil. Gully mending failed Washington on his Virginia farm as did horizontal plowing for Jefferson and other Atlantic coast farmers in the early days. After the continuous growing of cotton in the South, the soil, as a result, was left open to the weather, it was the terrace upon which many farmers placed their chief reliance. Now as then, with few isolated exceptions, a prescription calling for a single method of control is inadequate to stay the loss from accelerated erosion. On most soils under cultivation, particularly if there is any real slope to the land, many different measures are needed.

Here, then, is the central idea back of the numerous project areas scattered throughout the country. From the very beginning it has been the fixed purpose of the Department of Agriculture that these areas should demonstrate a coordinated counter attack against erosion on the farm and range. To do this it is necessary to employ every known device and to develop others in combination. Nowhere in the country can one find as many control measures and their varying combinations as are in use on projects in the Pacific Southwest.

These project areas, selected with the advice and approval of officials representing the experiment stations, the extension services, and the colleges of agriculture, are in reality proving grounds where farmers and other interested citizens may see the elastic combinations of control practices at work on the land. See map on back cover.

After a project area is selected, and prior to the making of any extensive plans, a careful survey is made on the farms of cooperating owners to determine the extent of erosion, the past use of the land, the slope of the fields, and the characteristics of the soil. When assembled and interpreted, the survey results form the basis for a control program. After a control program for the area is drawn up it is presented to farmers who are invited to participate in it. Those who are interested agree to apply definite erosion-control practices on their land for 5 years. The Service, in turn, agrees to provide certain technical and material assistance in carrying out the program.

A program to fit a farm, however, cannot be hastily developed. Accompanied by the farmer, representatives of the Service walk over every field, and together

they decide upon a course of action. The lay of the land, the soil, the climate, the markets, the cash and forage-crop requirements, the cost of water if irrigation is used, all these factors are taken into consideration and discussed. Rotations and tillage practices are discussed and agreed upon. Plans are made for the erection of new fences or the removal of old ones so that fields may be farmed on the contour. Severely eroded areas are to be planted with trees or grass. Irrigation systems are to be improved if necessary. In brief, each farm program is drawn to make effective use of modern soil- and water-saving practices.

Las Posas Project

The Las Posas project area—the first in California—is about 12 miles inland from the coast and about 60 miles north of Los Angeles. This 40,000-acre strip of land lies in one of the larger tributary valleys of the Oxnard plain which has been built up by sediments from a number of mountain streams, chief of which is the Santa Clara River. Topographically, the area is typical of southern California. The project area is a broad plain with contiguous, rolling to steeply sloping hills and mountains. The valley floor lies about 350 feet above sea level, but elevations rise abruptly in the nearby mountains, reaching a maximum of 2,350 feet on South Mountain along the northern boundary.

The early occupants of the land grew a little corn and other crops along streams where water could be diverted onto the land. But apart from these small acreages under cultivation a pastoral type of agriculture predominated throughout the area. Hides were traded for merchandise at the seacoast. In the late fifties, and with the rising tide of settlers, citrus fruit, walnuts, and lima beans were introduced.

In more recent years these coastal lands, of which the project area is a part, have produced as high as 70 percent of the world crop of lima beans. Today the bean acreage, including both blackeye and lima, occupies 37 percent of the land area in the project. Grains, consisting largely of barley cut for hay, occupy about 15 percent of the area. Walnuts occupy 510 acres, and citrus fruit 621 acres. Uncultivated land occupies about 42 percent of the area, but some of this uncultivated land, now either idle or used for grazing, once grew beans.

All the citrus acreage is under irrigation, and slightly more than half of that devoted to beans is irrigated. Most of the walnut acreage is also under irrigation. Some of the irrigated beanfields are on slopes as steep as 20 percent while dry-farmed beans may be found on slopes above 50 percent. Nearly all the citrus plantings are on an irrigation grade, and terraces have been developed in most of the groves which are planted on steep slopes (fig. 27). Walnut groves, for the most part, occupy the friable soils on gentle slopes.

Even under undisturbed natural conditions much soil moved down the slopes to build up the broad alluvial plain. This movement of the soil was slow compared with that which now occurs during the occasional heavy rains. It is

probable that at no place in the United States have conditions such as soil, climate, and land use combined more effectively to move soil toward the sea (fig. 28).

Rain normally falls on this soil during the winter months; little or no rain falls from March to November. Average precipitation is a little over 12 inches, but owing to the torrential rains and the dry, clean cultivated soil, the damage by erosion is severe. Within the boundaries of the project every type of water erosion may be found, ranging from sheet erosion on the higher, dry-farmed slopes to the gorgelike barrancas that slash their way, often 75 feet deep and 100 feet wide, through the $1,500-an-acre walnut and citrus land on the lower plains.

FIGURE 27.—Citrus plantings on an irrigation grade. Terraces have been developed in this grove which is planted on a steep slope.

One strip of a road across the Oxnard plain when originally constructed was on a fill about 4 feet above the fields on either side. Erosion over a period of years, climaxed by the flood of March 2, 1938, caused the land on each side of the road to become level with the roadbed itself. It is not uncommon to find irrigated fields in the flats that have been raised as much as 2 to 2½ feet with depositions in 2 years' time.

Fifteen years ago a farmer installed a pipe line on the shoulders of his irrigated beanfield to carry water away from the cross dikes. At the time of installation he had 18 inches of clearance between the subsoiler penetration and his pipe line. The subsoiler cannot be used now because it would strike the exposed pipe.

The most difficult problem in erosion control in this area is confined to the dry-farmed bean land. Appended to this problem are many interrelated difficulties for which there is no immediate solution. Practically all of this bean land

is potentially good for citrus or walnuts and perhaps other more valuable crops if and when water can be brought to it. Landowners who have prospects of selling their land at the so-called citrus prices during a real estate boom are inclined to raise beans and take their chances on erosion losses. Moreover, about one-half of the dry-land bean farms are operated by tenants who cannot obtain more than a 1-year lease.

From the standpoint of comparatively easy cash returns from these lands for any one year, no crop has yet been found to take the place of beans. Oats and barley at prevailing prices would scarcely pay taxes. Dairymen and a few race-horse owners provide a limited market for hay, but the best prices in this market are provided by the race-horse owners who do not want legumes in the hay mixture. More livestock on the land to consume home-grown hay might be a solution to the problem if a future adjustment can be made in land valuations and taxation.

While the appropriate combinations of strip cropping, terracing, contour farming, crop rotations, and other control measures have proved hopeful in saving soil in these dry-farmed beanfields, their application has not been sufficiently widespread to solve the problem.

FIGURE 28.—Soil, climate, and land use are such that soil moves quickly toward the sea.

In 1938 the University of California and the Soil Conservation Service established an experimental farm in this project area in order to test additional control measures, along with cropping practices and tillage operations on the dry-farmed bean land.

Unirrigated alfalfa has proved of value as a forage crop where land operators are willing to keep livestock as a part of the farming program. Many acres of eroding bean land have been

retired to this vegetative cover, which retards erosion and can be either mowed or pastured, or both, for a period of from 3 to 5 years (depending on rainfall) before reseeding is necessary.

Since land values are high, especially in the irrigated areas, most farmers favor the use of concrete, rock masonry, oil-lined ditches, and other mechanical controls which would be considered too expensive in many other sections of the country.

Earth-fill dams of a drop-inlet type have proved very satisfactory in the Las Posas area (fig. 29). These structures have been built in sizes varying from a few to several thousand cubic yards. Dams of this type are frequently used in the large gullies which are very common in this area.

No basin listing had been practiced on the project area prior to 1934 when the Soil Conservation Service established the demonstration. Basin listing is now fairly common throughout the area, but it is not recommended on slopes greater than 6 percent on most soil types unless some kind of winter cover is planted at the time the basins are made.

Trees, shrubs, and grass, as elsewhere in demonstration areas, have been used in irregular spots retired from cultivation or in gullies where vegetation is needed for stabilization. Whenever possible vegetation is selected with the needs of wildlife (food and cover) in mind. The species of trees and shrubs used include eucalyptus, black locust, elm, Arizona ash, sumac, lemonade berry (*Rhus integrifolia*), and others. Of these the eucalyptus and black locust appear to be the most successful from the standpoint of growth and their ability to survive during the long dry summers.

FIGURE 29.—An earth-fill dam of the drop-inlet type in the Las Posas area.

When storm waters of the March 2, 1938 flood lashed these fields and farms, the control measures then established on the project area were subjected to the first severe test. A detailed survey was made after this storm. Of all the control measures installed, less than 1 percent was damaged by the flood, which broke all records of the past 25 years.

Farmers reasoned, and with wisdom, that if soil-saving measures could withstand a storm like this there was merit in their use. Partly as a result of the evidence provided by this storm and partly because of the results obtained during a 5-year demonstration period many farmers outside the area requested assistance. Within a year after the flood, 17 neighboring property owners requested help in developing plans. By July 1939 work was pending on 8 additional off-area farms comprising 14,344 acres.

In the project area 101 farms involving 18,243 acres were under agreement by July 1939. Treatment on 95 of these farms, involving 17,780 acres, was completed.

Caliente, Nev.

A stream named "Meadow Valley Wash" meanders through southeast Nevada for about 200 miles before it empties into Lake Mead some 30 miles above Boulder Dam. The first Nevada project of the Soil Conservation Service was established on this watershed in 1935.

The yearly average rainfall in this part of Nevada is low. In the high mountains beyond the project area both snow and rain may raise the average to as much as 12 to 15 inches, but the scant precipitation in the valleys lowers it greatly. Even though the lower elevations receive about 5 inches of rain in most years much of this precipitation may come in torrential cloudbursts. Two inches of rain have been known to slash down in 40 minutes.

The more favorable rainfall in the high mountains is sufficient for the growth of yellow pine although piñon and juniper predominate. Although the vegetation was probably always sparse in the higher lands outside of the timbered areas, old-timers tell about the lush grass in the Meadow Valley and its tributaries. Some say it was "belly-high" to a cow. And the stream, they say, once flowed clear and beautiful. Some remember winters when it was possible to skate the entire distance between Panaca and Caliente.

While the valley land now tributary to the stream supports a native meadow cover of Nevada bluegrass, some redtop, palatable rushes, and some sedges, the proportion of these is now very small compared with the original cover. Tall rabbitbrush and wild-rye border the cultivated meadowlands and occupy the lower hill slopes where little moisture is available. As gullies and draws deepen, thus lowering the water table, these less palatable types of vegetation creep down the slopes and replace better forage plants on the meadow floors (fig. 30). These

gullies in late years have grown to such proportions that they rival the barrancas of California. The few ranchers who depend on irrigated water for alfalfa, wheat, and vegetables have found the supply less and less dependable.

Settlers with their herds and flocks came into this high dry country as early as the seventies. Although livestock numbers have usually been more than the range could support without depletion of the vegetative cover, it was not livestock solely that caused the damage. In the early seventies when mining operations developed near Pioche and the surrounding district, the quantity of ore produced was second, in the whole Pacific slope area, only to the Comstock Lode. These early mining activities induced extensive logging operations in the best timbered areas of the upper drainages. Mining operations required timber for tunnels, shaft lagging, and fuel for the smelting of ore, as well as for the building of homes. A second intensive period of logging began about 1890 when the Oregon Short Line and Utah Northern Pacific Railway Co. undertook the building of the railroad through this particular section of Nevada. And later, in 1903, construction was commenced on the railroad south of Caliente. This called for more timber which was taken from the dwindling stands of the higher areas. Still later, in 1910 and following the New Year's Day flood of that year, when some 60 miles of railroad were completely destroyed, more timber was needed for reconstruction purposes. This time the railroad company constructed a "high line." In the building of the high line with its 15 tunnels, 7 of which are between Clover Valley and Caliente, much of the remaining timber was removed from the Ely Springs and Pine Canyon watersheds.

As stated in the November 2, 1937, report of the Union Pacific Railroad Co., the chronological succession of floods to 1911, inclusive, in the Meadow Valley Wash occurred in the following years, 1906, 1907, and 1910. Since 1911 available information indicates that floods of devastating proportions occurred in 1914, 1922, and 1938, with minor floods occurring at least twice each season.

The successful operation of industries within the entire drainage is dependent upon railroad facilities. Occasionally the mines near Pioche discontinue operations because the railroad tracks have been damaged and the ore and concentrates cannot be shipped. In March 1938 the tracks from Clover Valley to the Clark County line were so badly damaged that 3 weeks elapsed before western train service was available. The cost of making repairs on the railroad in the Meadow Valley Wash was $208,600.

Prior to 1910 there was no established channel through the bottom lands of the Meadow Valley Wash. The floods of recent years have increased the channel size until at the present time the farm land is probably only 50 percent of that in 1910. Not only have the gnawing gullies destroyed land that was formerly under cultivation, but the water table has been so lowered that much of the formerly good meadowland supports little more than rabbitbrush and greasewood.

Up to now the defense measures in use in the project area represent in the main a two-point program: (1) Grade stabilization and bank protection of the flood channels, and (2) improvement of cover on range lands.

FIGURE 30.—As the water table is lowered, the less palatable plants creep down the slopes and replace the better forage plants on the meadow floor.

Service technicians were handicapped at first in the construction of suitable check dams, drops, and water-spreading facilities. This handicap was due principally to the limited information available on the maximum water flow. Measurements and observations of the floodwaters in March 1938 provide suitable basic data from which more adequate structures may be designed.

Log-crib and rubble-masonry drops, as well as concrete soil-saving dams, have proved their worth in checking the spread of gullies and in raising the water tables in the valuable meadowlands (fig. 31). Tetrahedrons made from discarded auto frames are used for channel-bank protection. A few tetrahedrons were installed in the Virgin River prior to the March 1938 flood (fig. 32). They worked so well there that people at Bunkerville and Mesquite have constructed similar and additional revetments at other points along the river. Wire-rock mattresses, as well as wire-bound brush and rock "sausages," are other methods now in successful use.

These structures, of varying types, are counted worth their cost in flood protection and as soil savers in the more valuable meadowlands. But once you leave these areas and go up on the sparsely vegetated range lands it is apparent that less costly control measures are needed.

On range lands, and particularly where native brush and timber are scarce, the earth-fill dam with diversion outlets and spillways has proved to be an inexpensive but adequate structure for delaying run-off and increasing water penetration. Grade ditches, used to divert water from washes onto higher flat areas, have proved satisfactory. This type of control, however, requires considerable main-

tenance and more study before it can be recommended for range improvement.

The main objective of the above measures has been directed toward the improvement of cover, so that in time the cover itself will prevent run-off, thus making mechanical control unnecessary.

FIGURE 31.—C. C. C. boys built this dam in the Meadow Valley Wash. At the crest of the flood of March 3, 1938, 4½ feet of water passed over the dam.

FIGURE 32.—These auto-frame tetrahedrons, along with the brush and the plantings of willow and elm in the foreground, make an effective barrier against bank cutting.

A 3,800-acre area has been fenced near Panaca. Within this area an improved plan of grazing management is also in effect. Various types of grasses are under study to determine their potential use in restoring cover. While crested wheatgrass and a few other grasses have shown some response, they have not had sufficient trial to warrant a general conclusion.

Corralitos, Calif.

Corralitos, a pleasant-sounding Spanish word meaning little corral or barnyard, is the name of California's second soil and water demonstration. Headquarters were established at Watsonville in 1935. From sea level at the coast line the land lifts in successive stages to the crest of the Santa Cruz Mountains about 12 miles inland. In from the coast one finds bottom lands or a lowland flood plain. Beyond and above these are the low-lying terraces. Still higher lies the upper coastal plain with its amphitheater of hills and mountains in the background.

While the average rainfall over the entire area is about 38 inches, it is extremely variable from year to year. It is also variable within short distances on the project area in any one year. It may be as low as 8 inches or as high as 40 inches in the lower elevation of the area. Up in the nearby higher foothills or mountains the rainfall may be as much as 60 inches, or even more. Near the coast in 1938 the rainfall was 18.25 inches, while in the higher elevations it was 62 inches. As elsewhere along the coast, rainfall normally comes in the winter. Eighty-nine percent of the rainfall during the 1938 season came during December, January, February, and March. Small amounts of rain fell in November and April but none from May to October.

Variations in topography or rainfall are hardly more extreme than the soils. Soils on the project area alone represent over 80 distinct types or phases, representing 23 soil series.

As might be expected, the wide diversity of climate, topography, and soil characteristics produced a wide divergence in the native vegetation. The coast redwood is the tallest tree in the world. But within a few miles can be found low-growing range grasses that usually characterize the vegetation on areas far removed from the forests. In general, the redwoods predominate in the higher elevations. Lower down one finds shrubs and browse plants, and still lower on the valley floors there is a dense cover of grasses.

This valley, the Pajaro, was discovered by the Portola expedition in 1769 when Don Gaspar Portola led a group of 40 soldiers and 15 Indians. Father Crespi, the historian of the expedition named the stream "Rio del Pajaro" meaning "River of the Bird," since they found a huge bird that the Indians had killed and stuffed with straw.

Father Crespi wrote in his diary:

We travelled over plains and low hills well forested with very high trees of red color not known to us. They have a very different leaf from cedars and although the wood resembles cedars somewhat in color, it is very different and has not the same odor. Moreover, the wood of the trees that we have found is very brittle. In this region there is a great abundance of these trees and because none of the expedition recognizes them, they are named "redwood" from their color (palo colorado). We stopped near a lagoon [presumably Pinto Lake], which has much pasture about it and a heavy growth of the redwoods. While here many deer, elk, and wild fowl were seen.

In the main, a pastoral type of agriculture predominated in this 40,000-acre area prior to the influx of forty-niners following the gold rush. All of this land was once used as a pasture for horses stationed at the Santa Cruz fort, but when demands for foodstuffs were made in later years men found that the climatic and ecological conditions permitted the production of a wide variety of crops. Today about 50 different commercial crops are grown on the project area. These include deciduous fruits, grapes, bush berries, lettuce, strawberries, various summer row crops, winter row crops such as peas, and cereals for hay and grain.

FIGURE 33.—In 1937 check dams of willow brush were placed in this gully to retard erosion until vegetation could be established. Pampas grass and black locust have been planted above the dams.

About one-half of the entire area is extensively cultivated, and about 35 percent of the cultivated area is in apples. Up until 5 years ago it was difficult to find an apple orchard that was not clean cultivated.

Production of all crops differs widely owing to variations in soil, slope, and site conditions. Apple orchards may range in production from 3 or 4 tons per acre to 15 or 20 tons. Similarly the gross returns may range from a low of $60 to a high of $400 or more per acre.

In general, this is a rich area and erosion losses are not yet as extreme as in some other parts of California. Gullies have not taken on barrancalike pro-

portions, but upon approaching the shoulders of upland terraces or the lower foothills that are largely planted to apple orchards, the havoc of sheet erosion and gullying becomes apparent. It is here that the losses of soil and water are beginning to be appreciated in terms of declining yields.

Figure 34.—In 1939 the gully shown in figure 33 was under complete control due to the vegetation.

On one such farm the sons who inherited the land are now trying to hold soil around their trees and on slopes that did not trouble their father much in 1870. Gullies are fingering their way up through orchards that formerly bore abundantly. The sons, now realizing that something must be done, are seriously employing every possible safeguard against the downward rush of water.

The solution of the problem of erosion control in this area where little or no irrigation is used, in the main, involves a three-point program: (1) Proper land use, (2) a far wider use of close-growing vegetation, and (3) improved tillage practices and controls to handle surplus water.

As elsewhere in North America little consideration has been given to the topography in its relation to land use. Many square-planted and clean-tilled apple orchards may be found on slopes that are 40 percent or more. Even if a cover crop is used in these orchards and even if appropriate mechanical controls are applied, it is perhaps impossible to hold soil on some of these steeper slopes. The solution lies in a more appropriate use of the land. Trees will hold the soil in these critical areas. If they are given proper care and considered as a crop to be judiciously harvested, it is possible to receive revenue from land that is otherwise unproductive. Apart from the preservation of soil on steep slopes, and the protection of lower and more valuable lands, these plantings provide food and shelter for wildlife. Grass is not, as yet, a proven possibility for these critical areas. Furthermore, there are few units large enough to justify a livestock enterprise.

While climatic and soil conditions are favorable to the growth of several tree species, the best results, to date, have been through the use of eucalyptus and black locust. In a study of survivals after planting in 1935–36 it was found that on sandy to sandy loam soils with a partial brush cover deciduous species gave the best survival with 37.8 percent, the eucalyptus 36.5 percent, and coniferous species 29.4 percent. On sandy loam to loam soils with a grass cover, eucalyptus gave 81.3 percent, deciduous species 61.3 percent, and conifers 52.9 percent. The best survival on the poor site was the California native walnut with 66-percent survival, and on the good site was black locust with 93 percent. On poor sites in gullies, black locust has proved to be the best species so far as survival and growth are concerned (figs. 33 and 34).

During the season July 1, 1937, to June 30, 1938, 75,500 trees were planted on 66 acres, and 20,060 additional trees were planted on gully-scarred acres.

Perhaps the most significant advance in the use of control measures has been through the use of cover crops on orchard land. Prior to 1935 practically no effort was made to establish winter cover crops. Growers depended entirely upon volunteer growth for protection during the rainy season and for the maintenance of the organic-matter content of the soil. By 1938 practically every one of the 150 farms under cooperative agreement with the Soil Conservation Service had some portion of orchard land under a vegetative cover. And this idea is spreading. During the rainy season of 1938 a planted cover crop was the rule rather than the exception, in the foothill orchard areas surrounding the project in Santa Cruz, San Benito, Monterey, and Santa Clara Counties.

From observations in the field and demonstration plots within the area, it has been found that cereals make an ideal erosion-resistant cover crop, and on certain soil types a legume mixed with the cereal would insure fertility. Cover crops make a greater early growth and are far more effective in erosion control if fertilizer is applied at seeding time. In addition to the hopeful increase in cover-crop acreage many farmers are now resisting the traditional urge to kill all vegetation as quickly as possible after the rainy season in the spring months. Many hold off cultivation until March 15 or later. When cultivation starts they disk lightly; just enough to stop cover-crop growth and still leave much of the residue on the surface. Two or three weeks later, when the danger of heavy rains is probably over, another disking may be done to further incorporate the plant residues with the soil. Both of these operations, in increasing instances, are on the contour—not up and down the slope.

Practical control for open cropland, where the income is much lower than in orchards, is more difficult to obtain. Some progress is being made, however. Contour cultivation, green manuring, strip cropping, crop rotation, basin listing, and the retirement of critical areas to pasture and woodland are included on some of the farms now under agreement. On one such farm contour strips, 50 feet wide, are planted to a 2-year rotation, a cereal hay, and a summer row crop. On another farm the contour strips are planted to a 3-year rotation of green manure, beans, and corn.

Some progress has been made in seeding pastures on idle land. A 15-acre field with slopes up to 40 percent was contour furrowed at 6-foot intervals. The furrows and berms were used for a seedbed. After one storm, water stood in some of these furrows for 24 hours and a good stand of grass was established. On other farms seedbeds in 30-foot contour strips with 20 to 30 feet of uncultivated area between have produced good stands of grasses. The uncultivated strips eliminated erosion of the seedbed by spreading the run-off water.

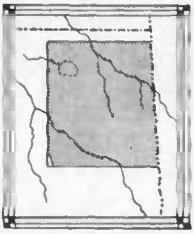
While most of the orchard men in this area are usually willing to make generous expenditures for mechanical controls for erosion, the lower prices for apples during the last few years have made it necessary to practice economy. Effort has been made to develop controls that a grower could establish with materials available on the farm. This type of control has been mainly used in gullies and small stream channels. Willow posts, junk cable, redwood lumber, and logs, and similar materials have been used successfully.

On some of the larger streams, where bottom land is jeopardized by bank cutting, several installations of either open octahedrons (fig. 35) or eucalyptus log revetments have been established.

One of the most damaging rains in the area since the establishment of the project came in a storm from December 10 to 12, 1937, when over 8 inches of rain fell. This storm provided the first severe test for erosion-control practices. It showed the weak and strong points of the soil- and water-saving safeguards. This storm probably had as good an effect as any other in obtaining the widespread use of cover crops in the apple orchards.

FIGURE 35.—These barriers, constructed of old pipe, have been installed to protect the stream bank against cutting.

Spreading Control Through Soil Conservation Districts



THE TREATED FIELDS AND FARMS in project areas of California and Nevada, as elsewhere in the United States, have been helpful in demonstrating the coordinated attack against accelerated erosion (fig. 36). These fields and farms present a hopeful contrast to land where no control measures have been adopted. Yet it is generally recognized that a far wider application of safe farming practices must be employed if sufficient progress is to be made. Early in 1936 the Department of Agriculture concluded on the basis of experience that while control measures in use on the project areas may point the way, means must be found to treat whole bodies of land. Soil- and water-saving safeguards here and there benefit the treated fields and farms, but they do not stop losses from neighboring unprotected areas. In seeking a general procedure whereby owners and operators of farmland could spread the use of water- and soil-saving methods, the Department suggested that the States pass in their legislatures enabling acts establishing soil conservation districts. (See U. S. Department of Agriculture Miscellaneous Publication 293, Soil Conservation Districts for Erosion Control.)

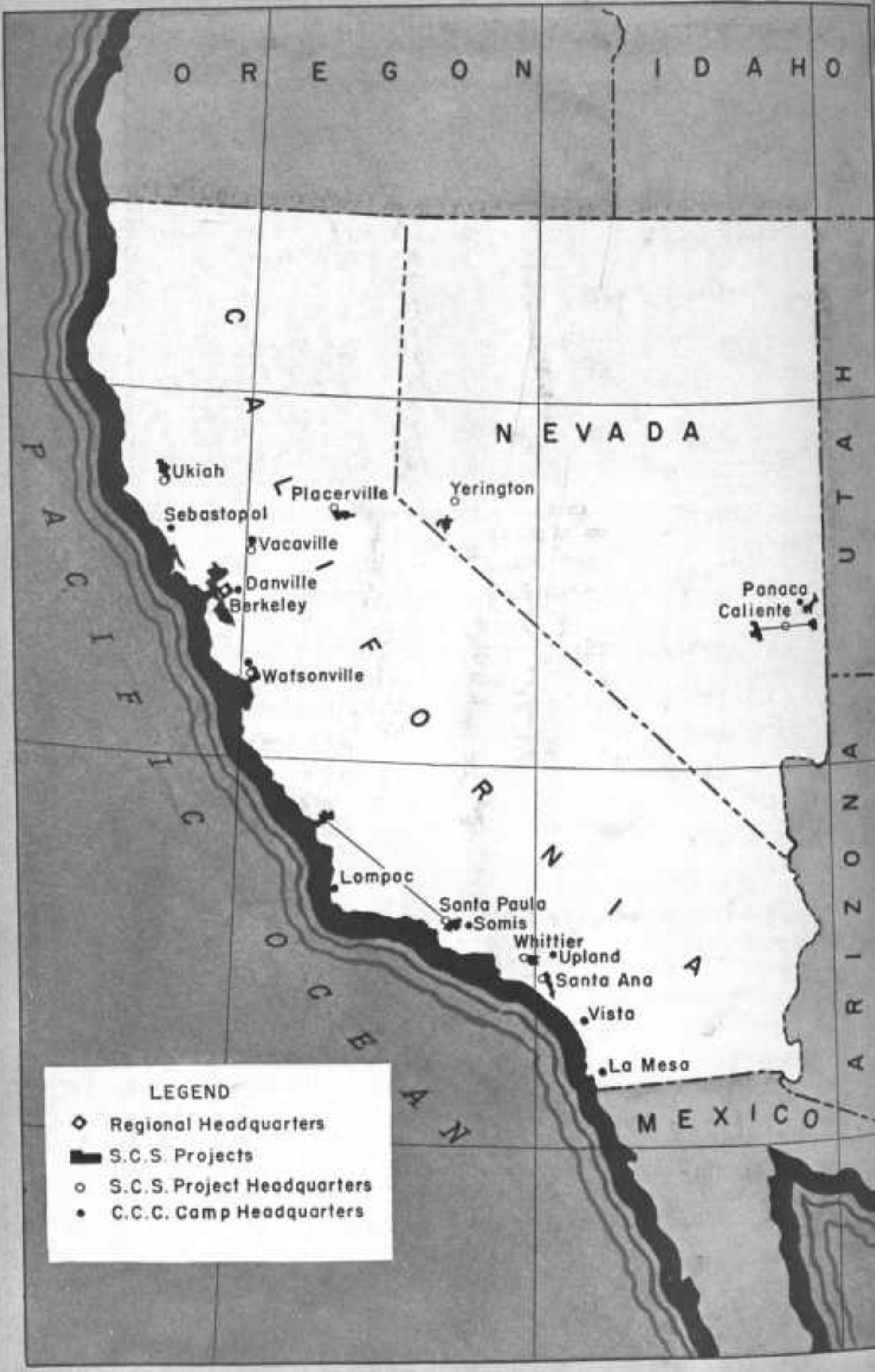
Enabling provisions for the establishment of conservation districts were passed by the Nevada Legislature in 1937. Similar legislation was passed by the California Legislature in 1938. Conservation districts either have been set up or are in the process of organization in both States.

Now that demonstration areas have proved helpful, and now that means have been established to spread the use of proven practices through conservation districts, it must not be assumed that answers to all the problems of erosion control have been determined. Only a start has been made. Research afield is still needed. It has not been determined yet, for instance, how to hold or save the rich bean land in the winter-fallow belt under the prevailing methods of farming. Too little is known about the possibilities of longer crop rotations and the diversification of farming enterprises. Likewise, too little is known about the possibilities of using plants, especially grasses native in many parts of the

FIGURE 36.—Project demonstration areas provide proving grounds where farmers may see erosion-control practices in operation.

area but heretofore not fully examined and utilized, as well as the possibility of introducing new plants.

Our lack of knowledge need not be permanent. The 1,087 farms in California and Nevada, where erosion-control measures had been established on 120,000 acres by July 1939, are teaching us rapidly. And if this knowledge can be brought into action on the land through conservation districts and by other means, substantial progress is in sight.


OREGON
IDAHO
CALIFORNIA
NEVADA
UTAH
ARIZONA
MEXICO
PACIFIC OCEAN
Ukiah
Sebastopol
Vacaville
Placerville
Yerington
Danville
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Watsonville
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